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THE TIME AVAILABLE FOR GRAIN DRYING IN SOUTH WALES

by C P Roe

Summary

The time available for drying grain in bulk dryers to a moisture content (MC.) of 16% - a typical requirement in Wales - is considered. The results suggest that drying to 18% MC is readily obtainable using unmodified ambient air, but that in order to achieve 16% MC, additional heating will be required.

1. Introduction

The rate at which stored grain deteriorates is governed largely by moisture content and temperature. In order to maintain quality and prolong storage life the grain must be dried to a safe moisture content. Drying in bulk is achieved by ventilating the stored grain (or seeds) with air of a certain relative humidity (RH), which will give the desired crop moisture content given sufficient time. Table one shows this relationship for two crops.

Table 1
Equilibrium moisture content-relative humidity (%) for various seeds at 15°C

	Crop moisture content %									
	10	12	14	15	16	18	20	22	24	26
Wheat	35	49	62	68	73	83	89	92	94	96
Barley	35	48	61	67	72	81	84	92	95	96

The drying capacity of the air depends on its RH and temperature. The higher the temperature, the greater will be its drying capacity at a given RH. Most drying should, therefore, be carried out immediately after harvest while ambient temperatures are high. In most bulk driers the RH is controlled to give the desired final grain moisture content and the input of heat should be limited to that which gives the desired RH (ADAS booklet 2416).

In Wales, the majority of grain is bought up from store at 16% MC for the animal feed industry (J Robertson, private communication). This paper considers the time available to dry grain with ambient air to this MC at two meteorological stations in South Wales. The reduction in time taken by various thresholds of heat input to the ventilating air are also considered.

2. Method

The temperature rise ΔT required to reduce ambient RH to a desired level X is given by the equation:

$$\Delta T = \frac{17.269T + (T + 237.3) \ln \frac{RH}{X} - T}{17.269 - (\frac{T}{237.3} + 1) \ln \frac{RH}{X}}$$

Where T = ambient air temperature
RH = ambient relative humidity.

FH2B

The derivation of this formulae is along similar lines to that described by Cochrane and is shown in Appendix 1.

Hourly meteorological data for Aberporth and Rhoose for a 10 year period (1974-83) have been analysed to show:

i. the average percentage of time with relative humidity of the ventilating air below stated thresholds;
ii. the average time available for drying grain to various moisture contents using unmodified air;
iii. the time available for drying grain to 16% MC for various heat inputs on a years in 10 basis.

Throughout the calculations the following assumptions have been made for simplicity:

a) that ambient air being drawn through a fan will experience a friction-induced temperature rise giving a lowering of relative humidity of 5% (McClean, P96). For the purposes of this study the relationships of ambient RH to ventilating air RH and equilibrium MC are shown below:

Ambient RH	≤ 80	≤ 90	≤ 95
Ventilating air RH	≤ 75	≤ 85	≤ 90
Equilibrium MC	16	18	20

b) that a 1°C rise in air temperature is approximately equivalent to a fall in RH of 5% (ascertained from a relative humidity chart Fig 1).

3 Results and discussion

3.1 Relative humidity variation

The percentage time with ambient RH at or below 80, 85, 90 and 95% thresholds are shown for each month in Fig 2. The percentage time is expressed as a proportion of the maximum possible over the 10 year period. There is little difference in RH levels between Aberporth and Rhoose and also between months. This latter point agrees with the findings of Keers (1984) in a study of humidities at Shawbury, Shropshire.

3.2 Time available for drying grain using unmodified air

Fig 3 shows the time available (expressed as a % of the maximum possible) for drying grain to moisture contents of 20,18 and 16%. Mechanisation advisers recommend that grain be dried to 18% by operating fans continuously with no heat (ADAS booklet 2416, P33). Fig 3 suggests that for approximately 70% of the time ambient RH conditions will allow this equilibrium MC to be reached; drying during more humid conditions overnight will be slow, but continued ventilation will keep the damp grain cool and prevent deterioration. For a 16% MC, unmodified air will only aid drying for between 30 to 40% of the time, and can actually increase the MC for the other 60-70% of the time and so either the fan must switch off when the ambient RH exceeds 80% or the heaters must be switch on. The available drying time during September and October is less than in other months at Rhoose.

3.3 Time available for drying grain using various heat inputs

Increasing ventilating air temperatures by more than 5°C in bulk drying systems usually results in over drying the bottom layers and condensation and premature mould development in the upper layers (ADAS booklet 2416).

A modicum of heat, however, is essential in the latter stages of grain drying and can result in a considerable time saving in achieving the equilibrium MC. Figures 4a and 4b show the time available to dry grain to 16% MC for various heat inputs on a years in 10 basis at Aberporth for July to October.

Heat inputs of $\leqslant 1$, $\lesssim 2$ and $\lesssim 3$°C show the amount of heat necessary to maintain the ventilating air humidities at or below 75%. A heat input of up to 3°C would give humidities $\leqslant 75\%$ for around 90% of the time. Clearly most heat will be required overnight when humidities tend to be higher. The disadvantage of costly electricity is not nearly so great as in years gone by since the introduction of Economy 7 cheap overnight rates.

4. Conclusions

In Wales the requirement for grain to be dried to 16% MC for the animal feed industry provides plenty of opportunity to dry grain in stages using unheated air. Only in the final stages of reducing from 18 to 16% MC is heat likely to be needed. Grain which is to be dried to less than 16% MC will require heat input, especially overnight. The introduction of Economy 7 has helped considerably in reducing overnight heating costs in order to maintain a suitably low relative humidity, thus enabling 24 hour drying in the latter stages of the drying process.

5. Acknowledgements

The help and guidance offered by Dr John Starr, Agro-meteorological Officer for Wales, is much appreciated.

6. References

ADAS	1982	Bulk grain driers. Grain drying and storage No 2. Booklet 2416.
Cochrane, J	1980	Time available for grain drying by ambient air. Agric. Memo 904*
Keers, J F	1984	The variability of relative humidity for grain drying. Agric. Memo 974*
McClean, K A	1980	Drying and storing combinable crops Farming Press Ltd.
Rosenberg et al	1983	Microclimate: The biological environment. John Wilby & Sons, Inc.

(*Copies available from Met-Office Library, London Road, Bracknell, Berks.)

Any comments or suggestions on this paper should be sent to the author.

KEY WORDS

GRAIN DRYING/BULK DRYERS/AMBIENT AIR

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Appendix

DERIVATION OF GRAIN DRYING FORMULA

Rosenberg et al (1983, P170):

$$SVP = 0.61078 \exp\left(\frac{17.269T}{T + 237.3}\right) \quad -(1)$$

T °C

SVP = KPa

$$SVP = \frac{VP \times 100}{RH} \quad \text{ie. } RH = \frac{VP}{SVP} \times 100 \quad \text{or} \quad VP = \frac{SVP \times RH}{100} \quad -(2)$$

Substitute (1) into (2)

$$VP = \frac{0.61078}{100} \exp\left(\frac{17.269T}{T + 237.3}\right) \quad RH-(3) \text{ at temp T, RH unknown}$$

$$\text{or } VP = \frac{0.61078}{100} \exp\left(\frac{17.269T^*}{T^* + 237.3}\right) X - (4) \text{ at temp } T^*, \text{ RH} = X$$

(VP is the same in (3) and (4) because the moisture content is unchanged)
Equating (3) and (4), to find expression for T* and hence ΔT

$$e^{\left(\frac{17.269T}{T + 237.3}\right)} RH = e^{\left(\frac{17.269T^*}{T^* + 237.3}\right)} X$$

Taking logs,

$$\frac{17.269T}{T + 237.3} + \ln\frac{RH}{X} = \frac{17.269T^*}{T^* + 237.3}$$

$$\frac{17.269T + (T + 237.3) \ln\frac{RH}{X}}{T + 237.3} = \frac{17.269T^*}{T^* + 237.3}$$

$$\frac{T + 237.3}{17.269T + (T + 237.3) \ln\frac{RH}{X}} = \frac{T^* + 237.3}{17.269T^*} = \frac{1}{17.269} + \frac{237.3}{17.269T^*}$$

$$\frac{(T + 237.3)\,17.269 - (17.269T + (T + 237.3) \ln\frac{RH}{X})}{(17.269T + (T + 237.3) \ln\frac{RH}{X})\,(17.269)} = \frac{237.3}{17.269T^*}$$

$$\frac{(237.3 \times 17.269) - (T + 237.3) \ln\frac{RH}{X}}{17.269T + (T + 237.3) \ln\frac{RH}{X}} = \frac{237.3}{T^*}$$

$$\frac{17.269T + (T + 237.3) \ln\frac{RH}{X}}{17.269 - \left(\frac{T}{237.3} + 1\right) \ln\frac{RH}{X}} = T^*$$

$$\Delta T = T^* - T = \frac{17.269T + (T + 237.3) \ln\frac{RH}{X}}{17.269 - \left(\frac{T}{237.3} + 1\right) \ln\frac{RH}{X}} - T = \frac{(T + 237.3) \ln\frac{RH}{X}\left(1 + \frac{T}{237.3}\right)}{17.269 - \left(\frac{T}{237.3} + 1\right) \ln\frac{RH}{X}}$$

$$= \frac{1}{237.3} \frac{(T + 237.3)^2 \ln RH/X}{\ldots}$$

AG1

RELATIVE HUMIDITY CHART

Example 18°C W.B. 21°C D.B.
18/21 Lines meet at 75% R.H.
Take horizontal line from there to 65% R.H. Drop down to base.
= 23.5°C = 2½°C Temp. rise needed in drying air.

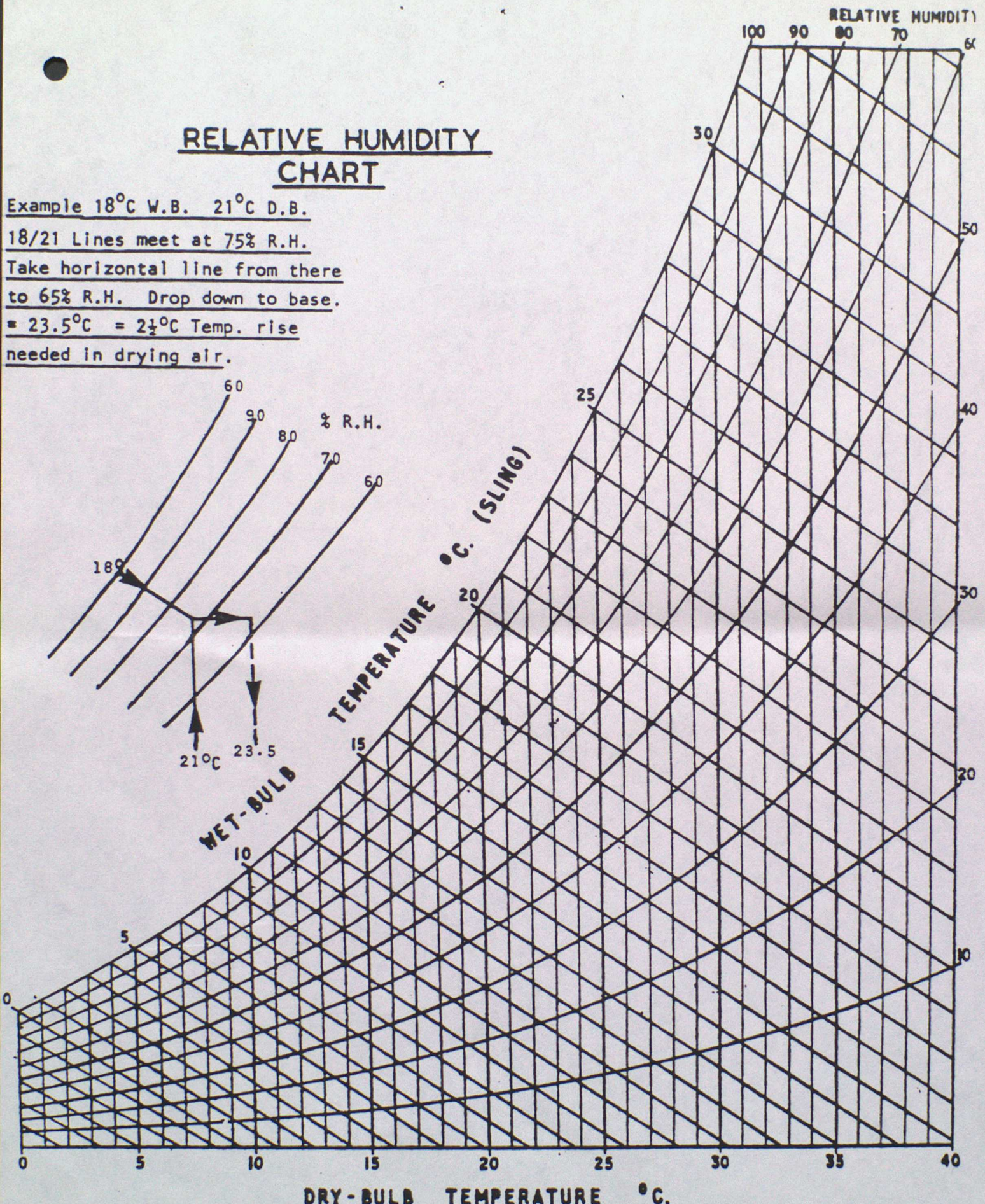


FIG 2

PERCENTAGE TIME WITH RELATIVE HUMIDITY BELOW STATED THRESHOLDS, 1974-83 AVERAGE (ALL HOURS)

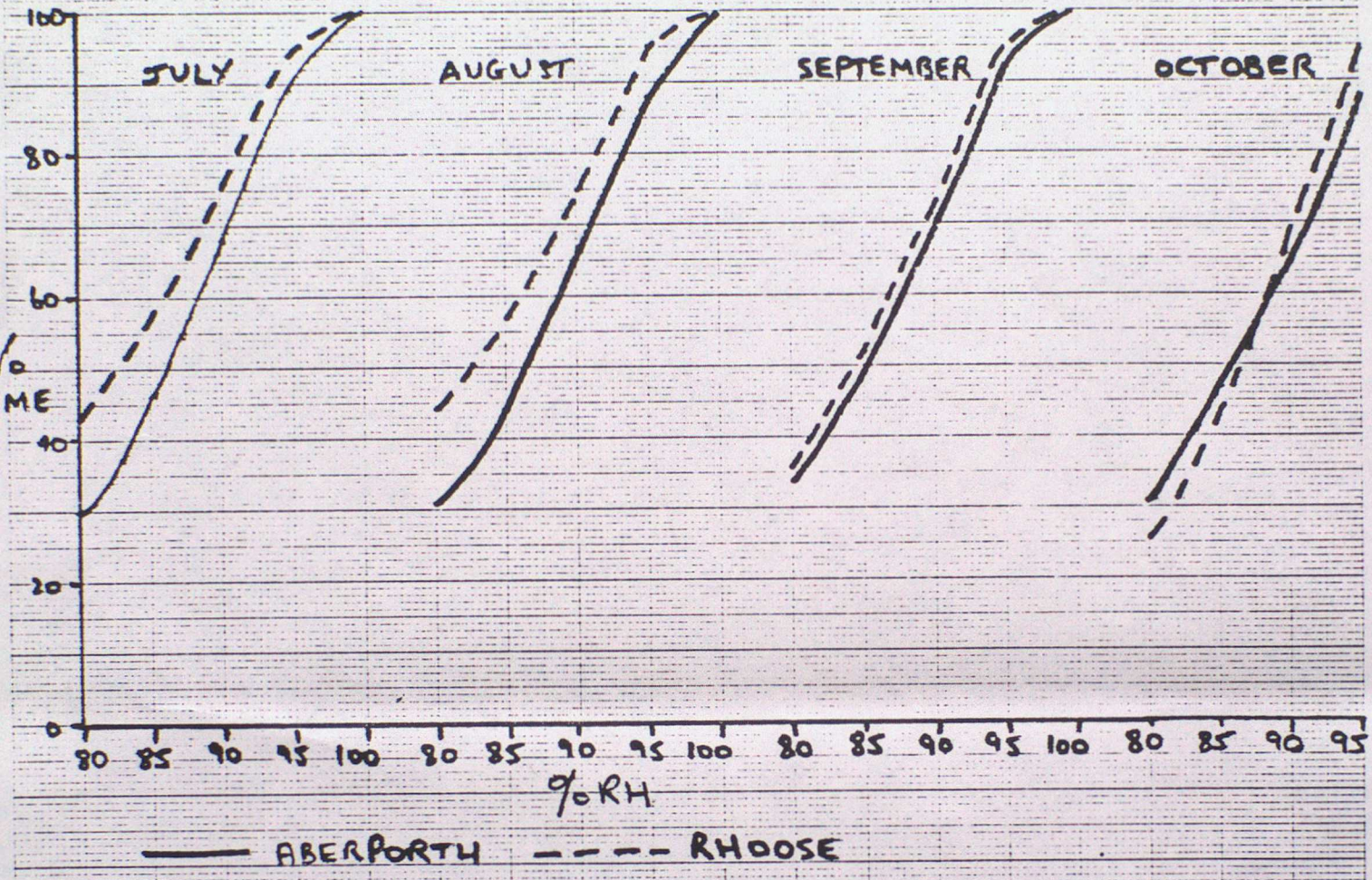
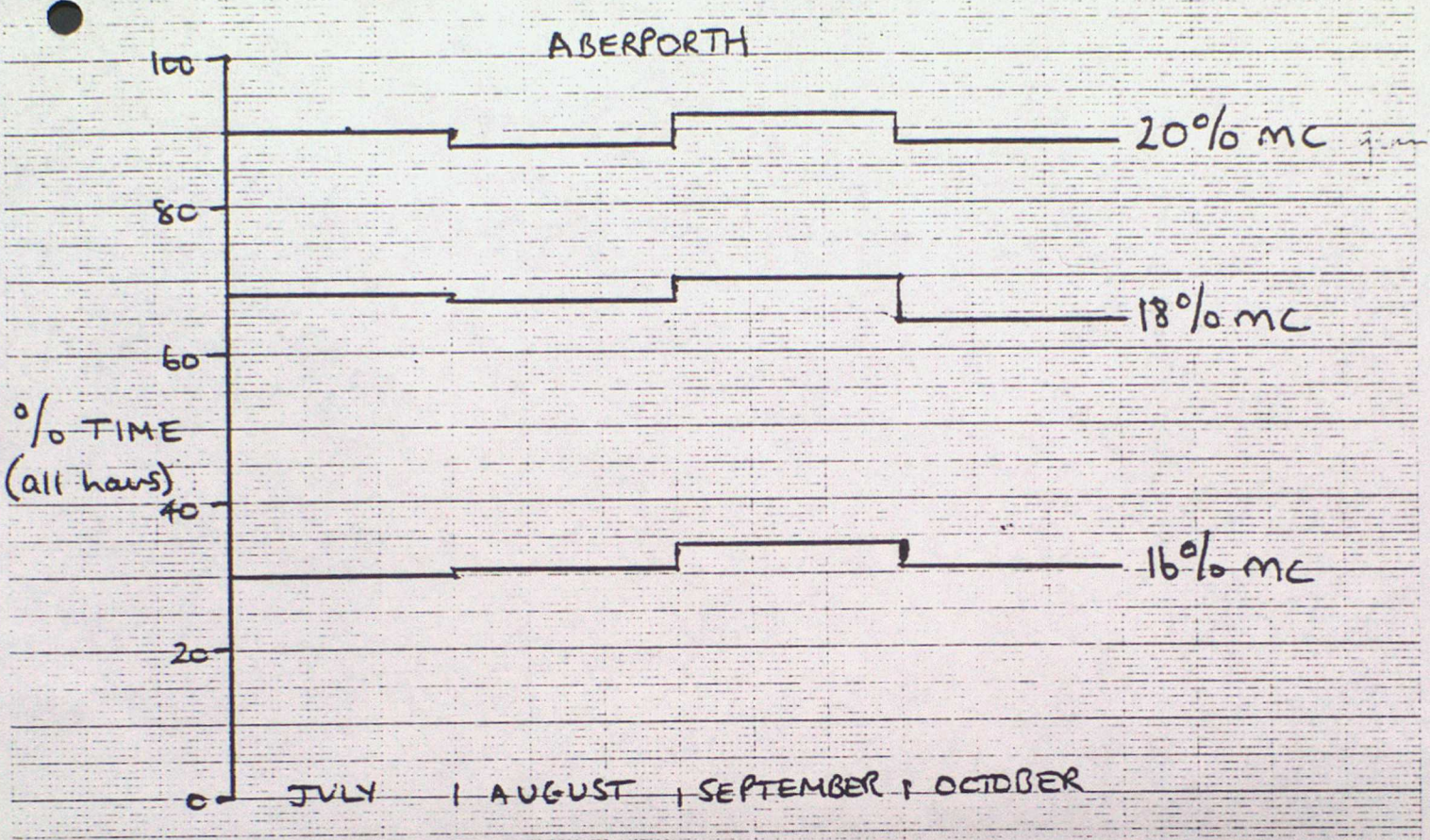


FIG 2.

TIME AVAILABLE FOR DRYING GRAIN TO VARIOUS MOISTURE CONTENTS USING UNMODIFIED AIR (1974-83 AVERAGE)



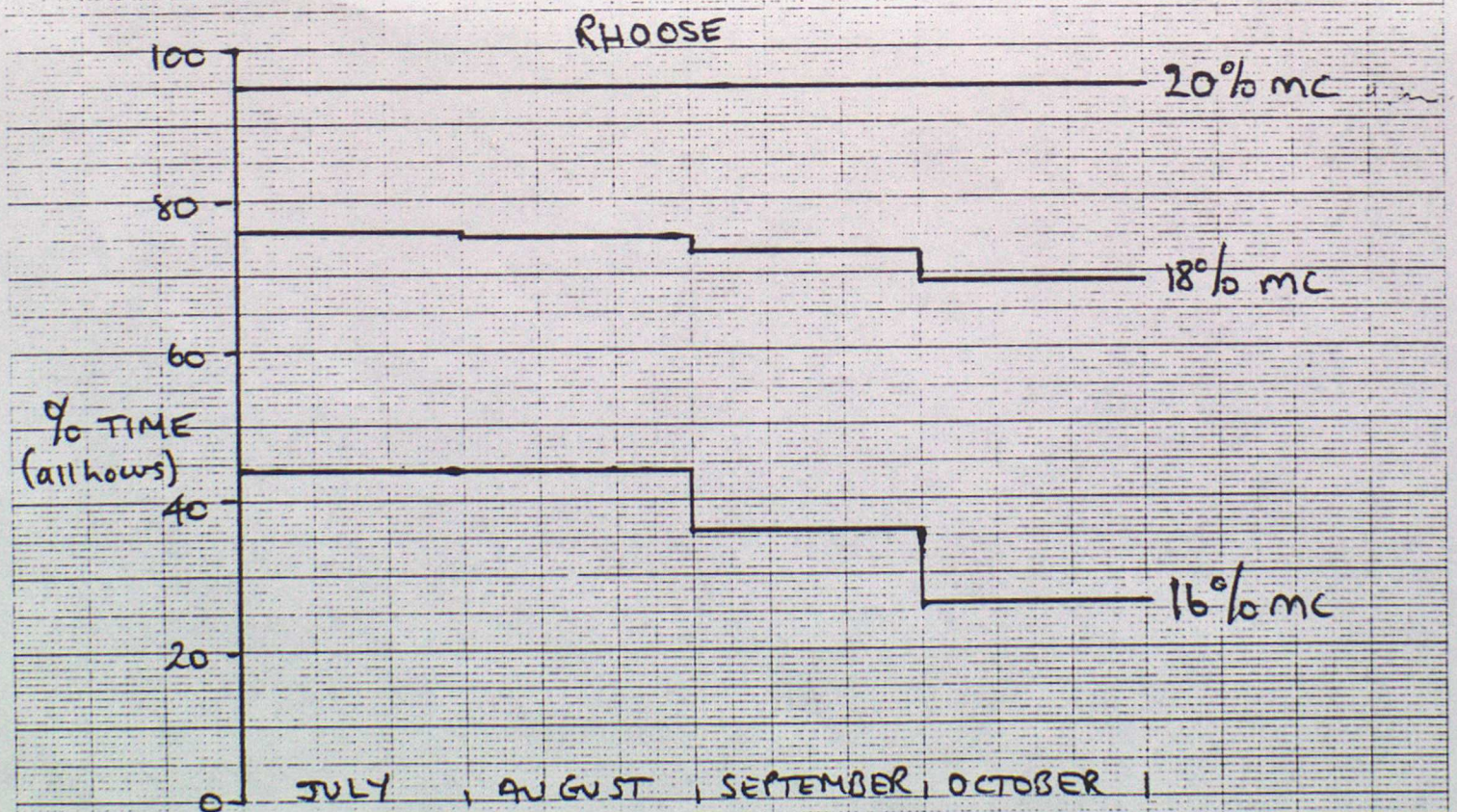
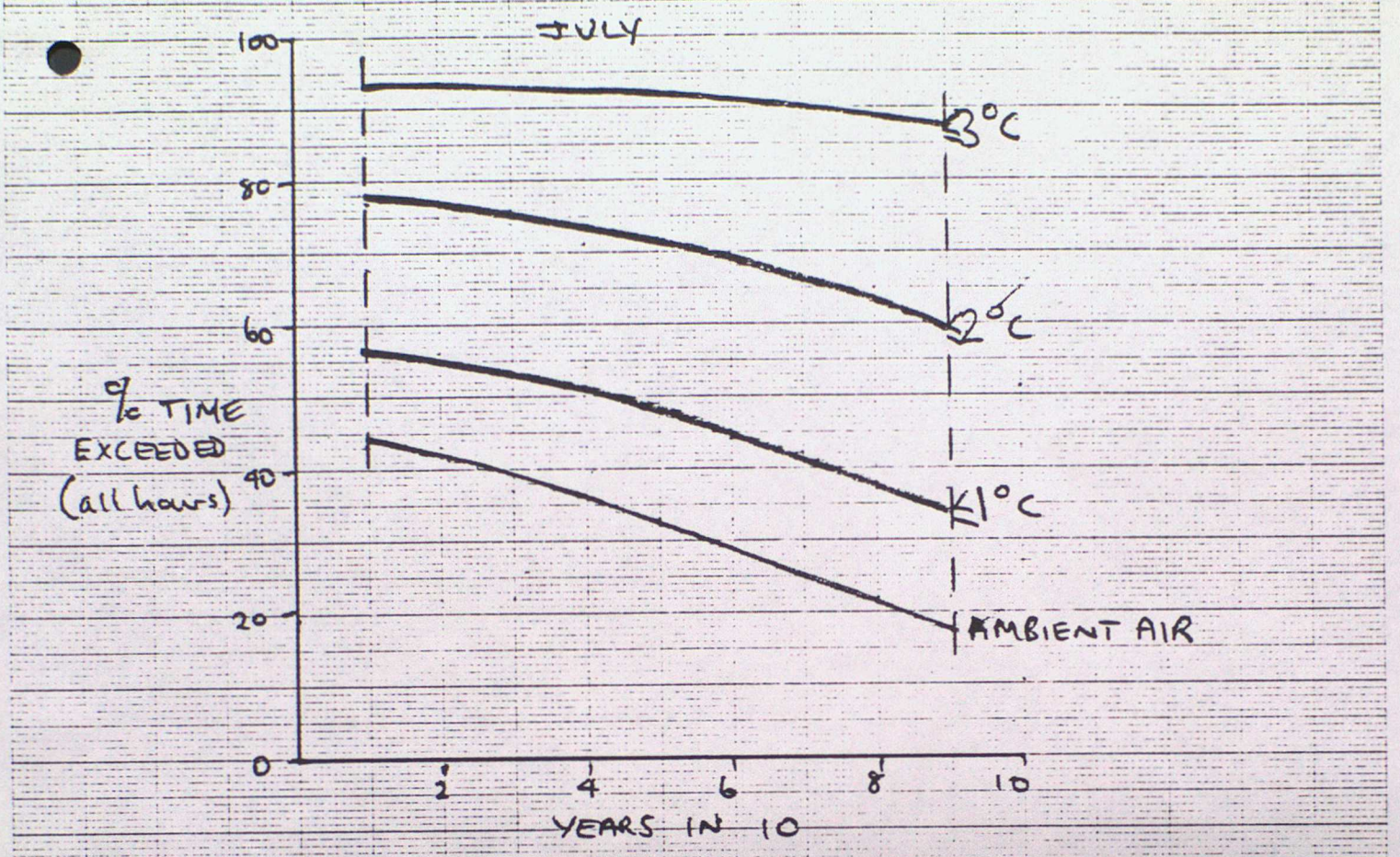


FIG 3a

PROBABILITY ANALYSIS OF TIME AVAILABLE TO DRY GRAIN TO 16% MOISTURE CONTENT FOR VARIOUS HEATING THRESHOLDS AT ABERPORTH, 1974-83



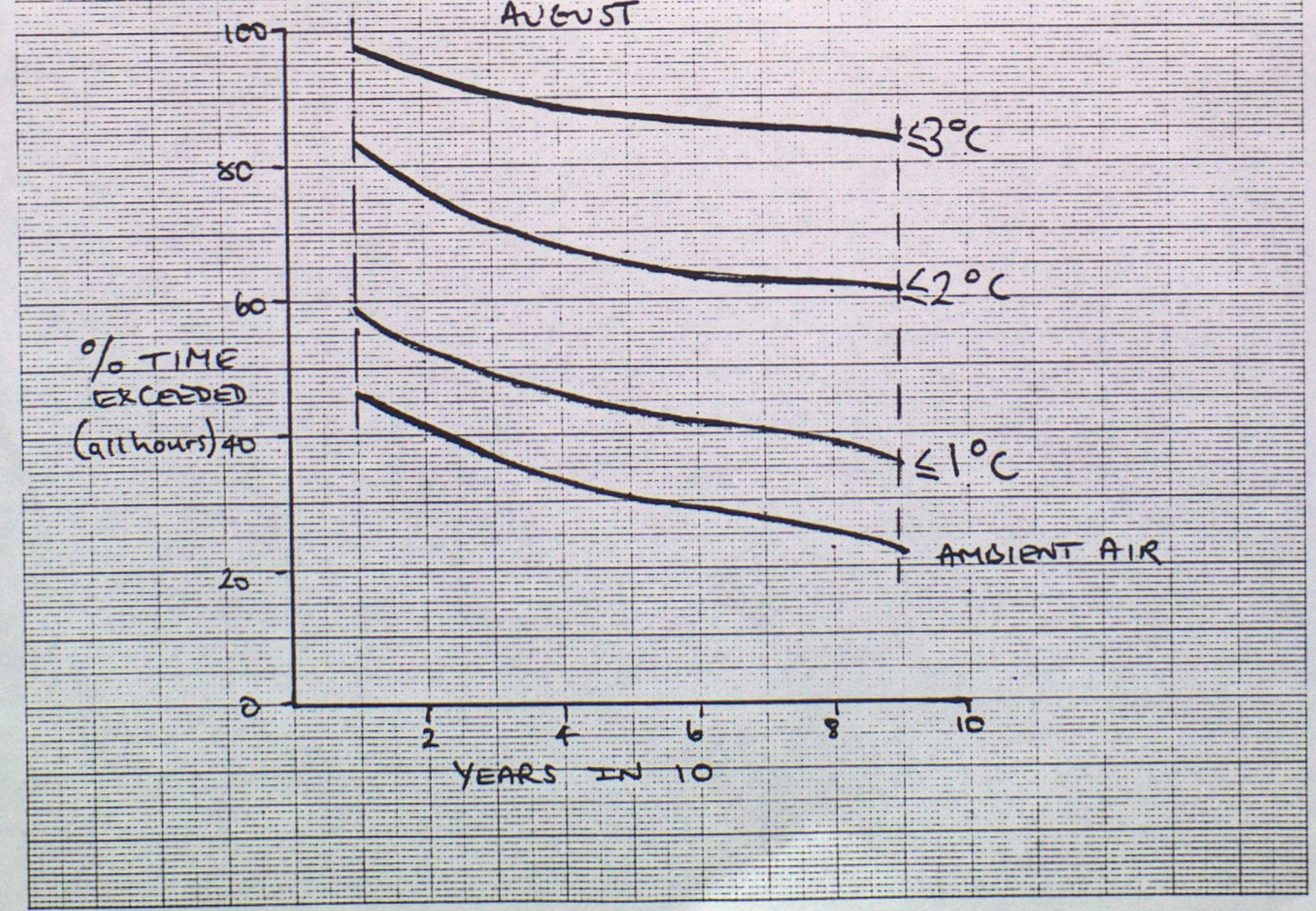


FIG 4b

PROBABILITY ANALYSIS OF TIME AVAILABLE TO DRY GRAIN TO 16% MOISTURE CONTENT FOR VARIOUS HEATING THRESHOLDS AT ABERPORTH 1974–83